Proceedings of a Workshop
IN BRIEF

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Atlantic Offshore Renewable Energy Development and Fisheries

Proceedings of a Workshop—in Brief

The production of offshore renewable energy is in its early stages in the United States. The development of offshore energy on the U.S. Outer Continental Shelf (OCS) is overseen by the Bureau of Ocean Energy Management (BOEM). In support of its mission to conduct its activities in an environmentally and economically responsible way, BOEM engaged a steering committee of the National Academies of Sciences, Engineering, and Medicine to facilitate a workshop about the research and monitoring needed to assess potential impacts from offshore wind turbine installation and operation on fisheries on the Atlantic OCS. This activity is specifically focused on fisheries resources, and is one part of a suite of efforts by BOEM to understand the potential impact of offshore renewable energy on the environment.[1] This workshop was held on November 8–9, 2017, in New Bedford, Massachusetts. The steering committee focused its activities on southern New England, where several offshore wind leases are progressing toward construction. Representatives from research institutions, the fishing and wind industries, and state and federal governments were invited to share their perspectives and experiences to help inform and advance guidelines for monitoring impacts on fisheries from offshore wind projects. In her introductory remarks, Bonnie McCay from Rutgers University, who chaired the steering committee, explained that the purpose of the workshop was to have a forum for engagement of the range of stakeholders in the wind energy development process. The workshop included presentations and panel discussions, as well as open discussion among all workshop participants. A summary of the prepared presentations and panel discussions, including some clarifications and additional remarks that arose during the discussions with the audience, is described in this document.

To introduce participants to the status of offshore wind in the United States, James Bennett, Chief of BOEM's Office of Renewable Energy Programs, described BOEM's ongoing leasing activities in the Atlantic. To date, 13 competitive leases covering 1.4 million acres in the OCS have been sold, generating $68 million in sales. If fully utilized, these leases have the potential to generate more than 15 gigawatts of energy, sufficient to power 5 million homes. Leases are in place in every state from Massachusetts to North Carolina, with further lease sales to occur in the future. Three site characterizations—surveys of the lease area conducted by the lessees—have been approved by BOEM. Construction and operation plans are forthcoming and construction may occur as soon as 2020 for a research lease in Virginia and 2021 for commercial projects in southern New England. In his remarks, Bennett highlighted the need to balance the environmental and economic benefits offshore wind can bring through renewable energy and job creation, while conserving valuable existing ocean uses.

INTRODUCTION TO FISHERIES IMPACTS AND RESEARCH NEEDS IN SOUTHERN NEW ENGLAND

Concerns about intensifying the use of marine resources in the state of Rhode Island, including expectations for offshore wind development, led to the creation of a comprehensive spatial plan in the federal and state waters off Rhode

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[1] Environmental studies conducted to inform BOEM's Office of Renewable Energy Programs can be found at https://www.boem.gov/Renewable-Energy-Environmental-Studies.

Island known as the Ocean Special Area Management Plan (Ocean SAMP). Grover Fugate, Executive Director of the Rhode Island Coastal Resources Management Council (CRMC), described the engagement efforts to incorporate fishery activities into the Ocean SAMP. He distinguished between two types of information: (1) fishery-independent data, which are data about the resource itself, and (2) fishery-dependent data, which reflect the activities of the fishing industry. Fishery-dependent data are driven not only by the presence of fish, but also by factors such as market prices, historic inter-fisheries agreements, and regulatory restrictions. Fugate focused on the challenges of obtaining fishery-dependent data about fishing effort, the collection of which requires significant engagement with the fishing industry to develop trust that the data will be used appropriately and will be protected. For example, fishermen have a concern that limited data will create a static snapshot and thus an inaccurate portrayal of a dynamic resource and industry. Additionally, fishermen are protective of details such as which locations are most important and what time of year the areas are fished, but these details are critical for understanding the activities of the fishing industry.

Fugate described how information about fishing efforts had been considered in planning for offshore wind. When BOEM began identifying the area that would be available for wind energy development—known as a wind energy area (WEA)—on the OCS off Rhode Island and Massachusetts, data from fishing vessel navigation system records gathered during the Ocean SAMP process were aggregated from multiple fishing sectors in order to identify the most used areas. This way, Cox Ledge, an area of high importance to the fishing industry, was identified for exclusion from the WEA. Another avenue for engagement with the fishing communities is the Fishermen's Advisory Board (FAB), developed to provide input throughout the lifetime of activities in the Ocean SAMP area. The FAB can provide input to federal agencies like BOEM, and energy developers are required to consult with the FAB during their siting process. Despite the value of the FAB, several workshop attendees noted during the discussion that there are deficiencies when it comes to seeking input from the fishermen based in neighboring states, particularly New York, who would be impacted by a wind farm in Rhode Island.

Anna Malek Mercer from the Commercial Fisheries Research Foundation (CFRF) described the recent CFRF activities and the resulting report[2] in which they collected stakeholder input and provided recommendations to guide research and monitoring for impacts on fisheries resources from offshore wind. Mercer shared a map of the areas where wind farms may be built in southern New England: the Massachusetts, Rhode Island/Massachusetts, and New York WEAs (see Figure 1). CFRF gathered input from scientists, fishermen, and other stakeholders from New York to Maine about potential ecological impacts, both positive and negative, from offshore wind and the research that would be needed to assess these impacts. Stakeholders expressed concern that acoustic disturbances during the construction phase could cause either mortality or injury at high sound frequencies or alterations in spawning and migration behavior. CFRF also heard concerns about fishing exclusions from the wind farm area during construction. During the wind farm operation phase, possible impacts include alterations to habitat from scouring, sedimentation, and the creation of artificial reefs, which could drive changes in fish communities; oceanographic changes in upwelling/downwelling that could redistribute food sources or larval transport; the creation of electromagnetic fields (EMFs) around cables that could influence fish behavior; and the potential for continued exclusions of fishing vessels from the wind farms.

Mercer explained that a research plan is needed to assess the issues of concern and the impact on fisheries. Thus, CFRF outlined guidelines for research programs to be implemented during the pre-construction, construction, and operational phases of wind farms. Pre-construction research includes both the collection of existing data and traditional fishing knowledge, plus baseline monitoring for a minimum of 3 years at monthly or seasonal intervals. She said that monitoring during construction and operations should be designed to connect back to the baseline monitoring and to be integrated into broader regional research activities. Currently there are limitations to designing detailed monitoring plans because the configuration of wind farms, the technologies they will use, and the access of fishing boats remain unknown. However, Mercer identified broad approaches that would be part of monitoring plans, such as collaboration with all stakeholders, utilizing standards that make monitoring plans consistent, making data centralized and accessible, and communicating through a variety of methods to stakeholders. The report also recommends the use of regionally focused working groups to identify the particular research and monitoring needs within a region.

CHARACTERIZATION OF FISHERIES RESOURCES IN WIND ENERGY AREAS OF SOUTHERN NEW ENGLAND

Vince Guida from the National Oceanic and Atmospheric Administration's (NOAA's) Sandy Hook Laboratory and Kevin Stokesbury from the University of Massachusetts Dartmouth gave a broad overview of the physical habitat and biological resources present in southern New England as a starting point for a conversation about potential monitoring targets and objectives to assess impacts from offshore wind. Guida characterized the benthic habitat in southern New England. He

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[2] Petruny-Parker, M., A. Malek, M. Long, D. Spencer, F. Mattera, E. Hasbrouck, J. Scotti, K. Gerbino, and J. Wilson. 2015. *Identifying Information Needs and Approaches for Assessing Potential Impacts of Offshore Wind Farm Development on Fisheries Resources in the Northeast Region.* 79 pp.

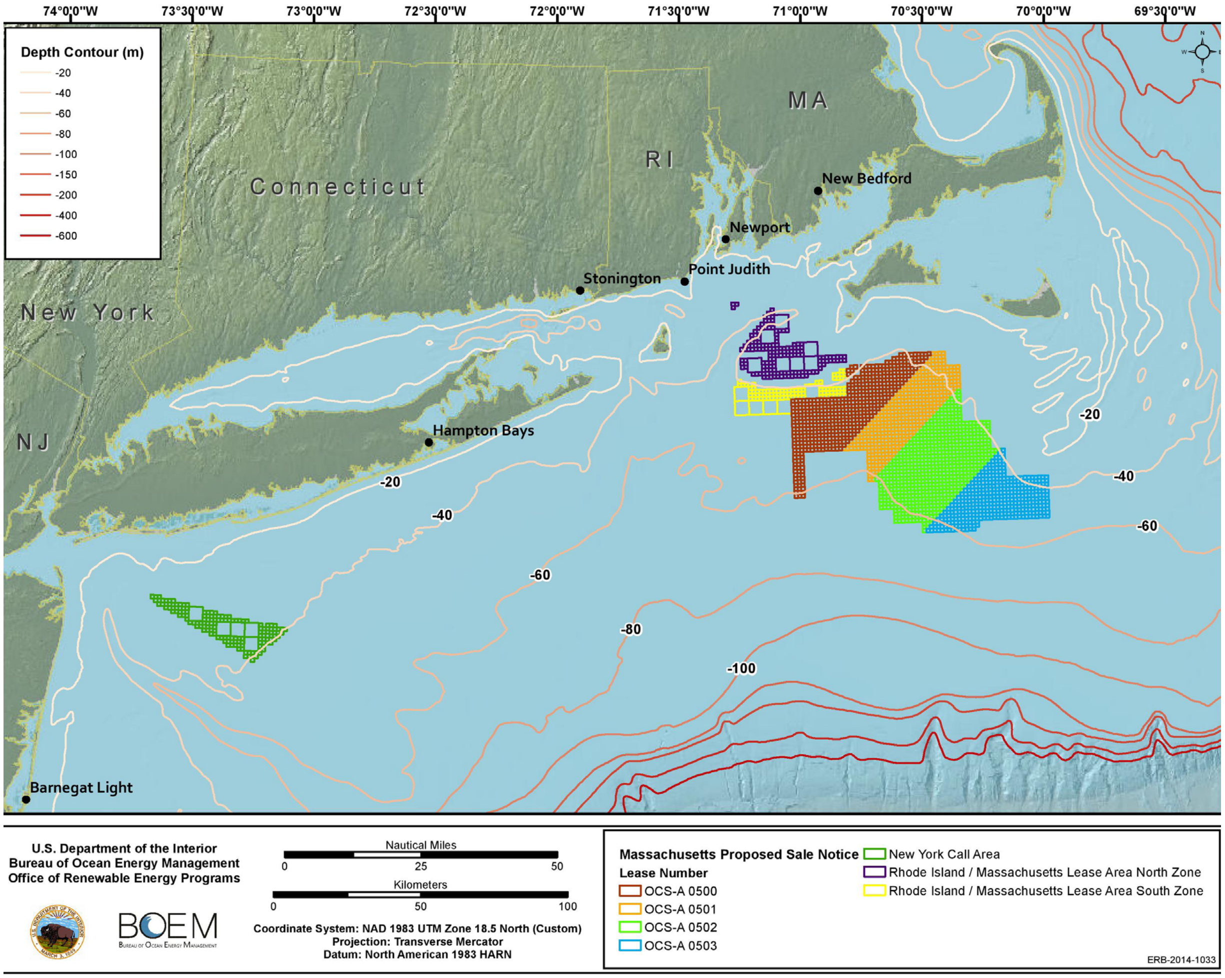

FIGURE 1. Wind energy areas (WEAs) in southern New England. Individual lease areas are identified in the Rhode Island/Massachusetts WEA and the Massachusetts WEA. At the time of the workshop, the New York WEA was also final with a lease in place. SOURCES: Presented by Anna Malek Mercer; figure from the Bureau of Ocean Energy Management.

explained that wind turbines are ideally built on relatively flat seabed and current technological limitations require wind turbines to be built in water that is 50 meters deep or shallower. About half of the Massachusetts WEA exceeds 50 meters in depth. The Massachusetts and New York WEAs are relatively flat and sandy, while the Rhode Island/Massachusetts WEA is more contoured and contains a mix of sand and rocky glacial features. He also described the pattern of seasonal temperature variation in the water column, where the temperature gradient between the surface and the ocean bottom is greatest in the summer and converges at colder temperatures in the winter. Driven by variations in environmental conditions, fish species seasonally redistribute themselves in the region.

Stock surveys show that a wide variety of fish species and benthic fauna are found within any one WEA, so the question Guida posed was how to identify which ones are vulnerable to wind energy development for inclusion in a monitoring program. He suggested four criteria for targeting species: (1) that a species is managed, and thus there is a mandate to protect it; (2) that it is limited to rare habitat features; (3) that it has a life stage that is immobile, or nearly so, such that it will be unable to leave an affected area; or (4) that the species is a “habitat engineer” that creates habitats for managed species. His resulting list of species based on these criteria are Atlantic cod and black sea bass due to their habitat limitations, shellfish (Atlantic surfclam, ocean quahog, and Atlantic sea scallops) due to their immobility, and longfin squid due to their immobile eggmops. These species can be found in the southern New England WEAs, which overlap with the essential fish habitat (EFH) of some of these species. However, he noted that species distribution data are imperfect because survey methods are not consistently well matched to the species being surveyed and more efforts need to be made to characterize their distribution. Despite this proposed process for narrowing down a list of critical species, he raised the question of whether unmanaged species or species outside of their EFH are also relevant targets for monitoring. During the discussion, some workshop attendees suggested additional species for monitoring, including flounder, skate, monkfish, and species involved in predator–prey relationships with key species.

Stokesbury described survey designs and techniques for characterizing biota within the WEAs. He emphasized that the environment is always changing due to natural variability and changing trends in climate, so a survey needs to be designed in such a way that significant changes can be identified and attributed to offshore wind development. He supported the use of the before-after-control-impact (BACI) survey design to identify significant changes. Stokesbury suggested that important characteristics to monitor include life cycle, morphology, spatial distribution, growth, natural mortality, and community structure. A particular effort he participated in was a survey within the proposed Massachusetts call area (the precursor to identification of the WEA) with the Fisheries Working Group on Offshore Wind. This working group surveyed for species including scallops, cod, winter flounder, and lobster and identified where they overlapped with the call area. The working group advised where the proposed area should be cut down in size based on areas of high overlap. Stokesbury also described an effort to create gridded regional maps in the north and mid-Atlantic, where each grid square is defined by the average abundance of 50 species and environmental characteristics, as a way to characterize the habitat in distinct areas without intensive data collection. This effort showed that the WEAs contained species of concern and benthic habitat distinct from the surrounding areas.

A panel discussion followed, involving members of the fishing industry who have been following developments in offshore wind. Lanny Dellinger from the Rhode Island Lobstermen's Association and chair of the Rhode Island CRMC FAB started the conversation noting that not enough research has been conducted to know exactly what the impacts will be. He believes that the early stage of development in the United States provides an opportunity to conduct rigorous research on the impacts of offshore wind, but in order for this to be possible, the development process needs to be slowed down to allow time for baseline data collection. Meghan Lapp from Seafreeze Ltd., a harvester and supplier of longfin squid and other species based in Rhode Island, later echoed this concern about the pace of development. She suggested that research on the impacts of offshore wind should be held to the standard of fishery research. She also emphasized that an additional necessary component of the research is the analysis of cumulative impacts every time a new wind farm is planned.

Panelists identified fish communities that could be impacted by the wind farm footprint. David Wallace from Wallace and Associates, who represents members of the surfclam and ocean quahog industry in federal and state regulatory processes, explained that wind turbines will be located on sandy bottoms at 50 meters depth or less, which is also the preferred habitat for clams. He expressed concern that this industry could lose significant value if there is a loss of habitat or if fishermen are excluded from fishing in the area. David Monti, a charter captain, fishing guide, and Vice President of the Rhode Island Saltwater Angler's Association, pointed out that fishing has been productive at the Block Island Wind Farm and has attracted many fishing boats; mussels have grown on the platforms and fish such as summer flounder and black sea bass have been prevalent in the area. However, he also noted that localized increases in fishing effort could have their own impact on the environment. Additionally, Bonnie Brady, Executive Director of the Long Island Commercial Fishing Association, cautioned that platforms may be aggregating individuals from elsewhere in the region without resulting in an overall increase in abundance. Lapp added during her remarks that the soft bottom benthic habitat is important for many species that will not benefit from an artificial reef created by the hard substrate of the turbines.[3] In addition to impacts on the fish species, Dellinger mentioned that there is a need for information about potential impacts to species at the base of the food web that commercial species rely on, such as copepods and other plankton.

The panelists described how the physical changes to the environment caused by wind farm development could impact valuable fishery species. Several panelists were concerned about possible impacts from noise during the construction (from pile driving and jet plowing), operations, and even surveying of wind farms. Brady pointed out that noise has been shown to impact marine mammals through hearing loss, behavioral modifications, and masking of other environmental sounds, and this could be a concern for fish as well. Possible impacts include injury or mortality caused by destruction of swim bladders from pressure waves, and changes in spawning, feeding, or migration behavior. Lapp also had concerns about the impacts on invertebrates, due to studies showing that cuttlefish may be injured by sound vibrations.[4] Brady expressed concern that EMFs created by the power cables could interfere with organisms that use EMFs for spatial location, movement, feeding, or mate finding.[5] Lastly, Lapp and Wallace both brought up the concern that wind platforms could alter ocean currents in a way that would affect larval transport and recruitment.

In addition to the impacts on the fish, the panelists were also concerned that fishermen would be excluded from current fishing areas that become the site of wind farms. Lapp and Monti both described the possibility that fishermen would be explicitly excluded from wind farms, with particular concern about losing access to the area around Cox Ledge in the Rhode Island/Massachusetts WEA. Monti identified tautog, cod, black sea bass, bluefish, dogfish, scallops, lobster, sharks, bluefin tuna, yellowfin tuna, monkfish, and skate as valuable species in that area. Fishermen could also be indirectly excluded from

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[3] Kritzer, J., M. DeLucia, E. Greene, C. Shumway, M. Topolski, J. Thomas-Blate, L. Chiarella, K. Davy, and K. Smith. 2016. The Importance of Benthic Habitats for Coastal Fisheries. *Bioscience* 66(4):274–285.

[4] Solé, M., P. Sigray, M. Lenoir, M. van der Schaar, E. Lalander, and M. André. 2017. Offshore exposure experiments on cuttlefish indicate received sound pressure and particle motion levels associated with acoustic trauma. *Nature Scientific Reports* 7:45899.

[5] Boehlert, G., A. Gill. 2010. Environmental and ecological effects of ocean renewable energy development: A current synthesis. *Oceanography* 23(2):68–81.

Block Island Wind Farm, Rhode Island (Credit: U.S. Department of Energy)

an area if they are unable to safely navigate within a wind farm. Lapp and Wallace both said that mobile gear, such as fish trawls and bottom-tending gear, require a lot of space because the gear is not easily controlled when towed. Wind turbines would be obstacles for this gear or would prevent safe navigation around other vessels or seabed obstacles, risking damage to expensive equipment. Steve Welch, a commercial fisherman from Massachusetts who has been serving as an advisor to research vessels mapping the Ørsted (recently known as DONG Energy) Bay State Wind lease, currently uses trawls to fish for monkfish and skate and agreed with the concern that some fishing gear would not be safe in the wind farms. Lapp identified signal interference with vessel radar as another safety issue caused by wind turbines.[6] This would be a problem for navigating in low visibility conditions and could impair Coast Guard search-and-rescue operations. Welch noted that even without direct restrictions, insurance companies could drive the exclusion of fishing vessels from wind farms by raising premiums for fishing within the farms. The panelists emphasized that exclusions or safety concerns inhibiting fishing in wind farms will compound the impact of restrictions already in place for managed fisheries.

The panelists emphasized the importance of engagement with the fishing industry in the offshore wind development process. Monti explained that each WEA or wind farm will have different potential concerns for the fishing industry and engaging fishermen is the best way to identify particular issues. Panelists expressed concerns that engagement has not occurred to the extent that it should. Specifically, Brady said that New York fishermen were left out of information-gathering discussions about space-use conflicts for offshore wind development in the Atlantic[7] and the Rhode Island Ocean SAMP. Brady emphasized that vessel trip reports and fishery data show that high amounts of fishing activity occur in the areas proposed for the WEAs. Lapp explained that a lack of trust builds when input from the fishing industry does not appear to be considered.

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[6] Ling, H., M. Hamilton, R. Bhalla, W. Brown, T. Hay, N. Whitelonis, S. Yang, and A. Naqvi. 2013. *Assessment of Offshore Wind Farm Effects on Sea Surface, Subsurface and Airborne Electronic Systems.* Final Report DE-EE0005380. https://www1.eere.energy.gov/wind/pdfs/assessment_offshore_wind_effects_on_electronic_systems.pdf.

[7] Brady referenced meeting locations identified in Industrial Economics, Inc. 2012. *Identification of Outer Continental Shelf Renewable Energy Space-Use Conflicts and Analysis of Potential Mitigation Measures.* U.S. Department of the Interior, Bureau of Ocean Energy Management, Herndon, VA. OCS Study BOEM 2012-083. 414 pp.

EFFECTIVE ENGAGEMENT OF THE FISHING INDUSTRY IN RESEARCH AND MONITORING

The next session continued the discussion on engaging the fishing industry in the offshore wind development process. Mike Cohen from the Holderness Fishing Cooperative in the United Kingdom described the activities of the cooperative, under which fishermen have organized to conduct research within local wind farms. He explained that fishermen seek to understand changes occurring in the environment so that they can adapt their fishing activities to changing conditions. Relationships between the fishing and energy industries are needed to design and implement monitoring programs that will collect data useful to the fishing industry. Cohen described a monitoring program at the Westernmost Rough wind farm, conducted as a partnership between fishermen and the energy company Ørsted. Fishermen in the cooperative are active participants in the research, beyond the use of their vessels for conducting surveys. The monitoring program included pre-construction baseline data collection and repeated monitoring post-construction. The focus of the program is commercial species, using commercial fishing techniques to monitor stock size, and data are collected on the condition of the fish. This partnership resulted in a monitoring program that exceeds statutory requirements and includes research into concerns important to the fishing industry.

Andrew Lipsky, Acting Chief of NOAA's Northeast Cooperative Research Branch, described the cooperative research currently under way in the northwest Atlantic. Cooperative research efforts include the collection of both fishery-dependent and fishery-independent data, as well as research on survey gear and model development. He emphasized that collecting fishery-dependent data on fishing activities depends on trust, which the program has been building over time. The program has worked with the industry to develop technology for crowdsourcing data from fishing vessels. The Fisheries Logbook Data Recording System (FLDRS) collects data on trip-level effort, gear types, catch level, species, location, oceanographic data, and the date and time of landings. FLDRS usage has added up to about 111 vessels reporting 110,000 individual efforts across many gear types and has significant industry participation in fisheries that overlap with the WEAs. Lipsky described the possibility of leveraging programs such as the Northeast Area Monitoring and Assessment Program (NEAMAP), which has collected fishery-independent data since 2007 in collaboration with the fishing vessel F/V Darana R. He suggested that NEAMAP and the study fleet are models that other regional surveys could follow or better utilize. Applying lessons from cooperative research to offshore wind research and monitoring, Lipksy emphasized the need to establish relationships with industry leaders to develop and prioritize research questions related to fisheries. Through the cooperative research program, there are well-established cooperative relationships already in place that could be useful.

A panel of people involved in cooperative research discussed their perspectives with the audience about the contributions that fishermen can make in monitoring the impacts of offshore wind. Several panelists noted that fishermen can provide information about fisheries that can fill gaps in research. Rob Ruhle, captain of the F/V Darana R, explained that fishermen have multi-generational knowledge regarding how fish respond to their environment, particularly, the environmental conditions they are attracted to and causes of their fluctuations over time and space. John Manderson from NOAA's Northeast Fisheries Science Center (NEFSC), who has worked extensively with fishermen, also noted that fishermen observe the environment on a fine scale, making daily observations of fisheries over many years. Katie Almeida from Town Dock Seafood in Rhode Island said that as a result of this knowledge and experience, many fishermen do currently participate in cooperative research, donating their vessel time and providing information that is important for economic and social science, as well as fishery science.

The panel discussed with the audience the role that anecdotal information could have in informing research and decision making. Several panelists noted that the long-term nature of anecdotal data can provide a picture of the natural variability of the environment. Ruhle suggested a specific value of anecdotal information as a replacement for baseline data in situations where there is not time for sufficient baseline data collection. Eric Hansen, a scallop fisherman from Massachusetts and captain of the F/V Endeavor, noted that landings data have often been ignored and he is interested in how to get data into the hands of people who will use it. McCay pointed to NOAA's Voices from the Fisheries project[8] as a way to systematically consider anecdotal information. She was cautious to distinguish between "traditional" knowledge, which has legal requirements for usage, and the broader range of knowledge gained through experience. However, one audience member noted that processes for incorporating traditional knowledge into offshore planning can still be used as a model for incorporating the broader field of experience-based knowledge. Tom Noji, a steering committee member from NOAA's NEFSC, noted that there is an opening for the use of anecdotal knowledge through EFH consultations.

The panel was posed with the question of who could implement and coordinate monitoring. Ron Smolowitz from Coonamessett Farm described his experience with the research set-aside program for scallops, in which the New England Fishery Management Council (NEFMC) sets aside part of the scallop fishing quota to fund sea scallop research. Under this program, priorities are identified by scientists with stakeholder input and competitive research proposals are subject to technical and management review. He noted that BOEM could set up a similar structure to fund fisheries monitoring in wind farms, using funds paid by the lessees. Representatives from BOEM said that a process for obtaining these funds from wind farms is not in place and would have to be designed, or alternatively, the lessees could volunteer the funding. Ruhle noted that there are existing datasets and surveys, such as those conducted by NEAMAP, that can be utilized for research on the impacts of off-

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[8] More information can be found at https://www.st.nmfs.noaa.gov/voicesfromthefisheries.

shore wind. Manderson agreed that a large amount of data already exists and that there need to be techniques for bringing it together and building trust across communities so it can be shared.

WIND FARM CONSTRUCTION AND DESIGN CONSIDERATIONS

The final session of the first day covered ideas about how fishery data and priorities can be used to inform the development of wind farms within established lease areas. Malcolm Spaulding from the University of Rhode Island described the model he worked on as part of the Ocean SAMP process to optimize the siting of wind farms and individual wind turbines. The model can incorporate fishery-based constraints, although this was not done for the Block Island Wind Farm. The model starts with an identification of "hard" constraints by including areas with adequate wind resources and excluding areas with other uses (e.g., shipping lanes, disposal sites). Within the remaining area, a Technology Development Index is calculated, which balances the potential for energy production with the cost of developing a structure in a given location. A Wind Farm Siting Index optimizes the micrositing of individual platforms within a farm by balancing power production, technology costs, ecological costs, and fishery costs.[9] Spaulding's model shows that alternative layouts to the one in the Block Island Wind Farm that maximize energy production and reduce fishery losses appear to be possible. The lesson Spaulding drew from the siting of the Block Island Wind Farm is that the investments made in the marine spatial planning of the Ocean SAMP were valuable for locating the wind farm, but additional micrositing techniques could have optimized the turbine placement further, including for consideration of fisheries.

Based on his experience with wind farm operations in the United Kingdom, Marcus Cross from Ørsted provided an overview of how energy companies design their projects, as well as how monitoring can be used to further inform their operations. Cross explained that an energy company considers many constraints when designing a wind farm, which are balanced against the need to design a profitable project. Projects are constrained by the physical environment, technology limitations, access to energy resources, potential social and economic impacts (including to the fishing industry), restrictions caused by existing ocean uses, legislative requirements, and environmental concerns. The planning stage of a project takes between 3–6 years and includes the development of an environmental impact assessment to identify potential impacts. Construction usually takes 1–1.5 years for the onshore phase and 1–2 years for offshore construction. Baseline data collection and monitoring may start pre-construction and continue during and post-construction. Cross described the purpose of monitoring as being able to check predictions and reduce the uncertainties identified in the impact assessment. Monitoring programs are driven by government initiatives, permit requirements, voluntary industry-driven programs, and academic research. Cross supported adaptable monitoring programs, emphasizing that they should be adapted to the needs of a particular site and be designed to answer the specific questions about potential impacts in that area. He noted that if monitoring programs are able to identify impacts to fisheries, this information may be used to identify opportunities for mitigating impacts. However, it is difficult for monitoring to trigger mitigation efforts because it is hard to attribute changes in the environment directly to the wind farms. Cross noted that BACI designs often produce large errors when implemented in variable environments and suggested that a gradient design, where sampling is conducted at regular distances from a turbine, may be able to provide more information.

PRIORITIES AND CHALLENGES OF MONITORING ECOLOGICAL IMPACTS

The second day of the workshop consisted of talks and discussions about how monitoring programs may be designed to identify impacts from offshore wind. In the first session, Andrew Gill from Cape Eleuthera Institute[10] framed the discussion around the need for monitoring programs to be designed to not only identify changes in the environment, but to identify whether the change is a meaningful impact. Additionally, changes need to be considered in the context of historic variability in order to be attributed to wind farms. He defined "effects" as being a response, change, or outcome caused by a stressor and "impacts" as effects deemed meaningful to biology, ecology, or technology. Gill described an example of a study that measured a change in the swimming speed of eels caused by EMFs from energy cables, leading to an increase in total migration time by 40 minutes.[11] While the EMFs may have affected swimming speed, there is no indication that this effect is a significant biological impact. He suggested that meaningful impacts would be effects on reproduction, survival, or fishing catches. Gill described a paper in which he and collaborators advocate for a reduction in data collection that does not have well-defined targets.[12] They advocate that monitoring should target metrics that can be linked to an ecosystem function or provision (like fisheries), should be useful for informing predictive models, and will aid in transparent and informed decision making. The

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[9] Grilli, A. R., Lado, T., and M. Spaulding 2012. A protocol to include ecosystem services in a wind farm cost model. *Journal of Environmental Engineering* 139(2):176–186.

[10] Gill is now with PANGALIA Environmental.

[11] Westerberg, H., and I. Lagenfelt. 2008. Sub-sea power cables and the migration behaviour of the European eel. *Fisheries Management and Ecology* 15:369–375.

[12] Wildling, T. A., A. B. Gill, A. Boon, E. Sheehan, J. Dauvin, J. Pezy, F. O'Beirn, U. Janas. L. Rostin, and I. De Mesel. 2017. Turning off the DRIP ("Data-rich, information-poor")—rationalising monitoring with a focus on marine renewable energy developments and the benthos. *Renewable and Sustainable Energy Reviews* 74:848–859.

paper recommends basing monitoring programs on management objectives, with specific metrics and thresholds identified. He added that stakeholder engagement is essential for this framework for there to be agreement on thresholds of change and on how to proceed with making decisions in the face of uncertainty.

Steven Degraer from the Royal Belgian Institute of Natural Sciences described the characteristics of effective monitoring programs to identify meaningful environmental change. In Belgium, energy companies conduct mandatory monitoring programs as a requirement of their environmental permit. By improving understanding of environmental impacts, monitoring programs can inform mitigation activities and future policy and management. In Belgium, monitoring is financed by the wind industry, coordinated by the Royal Belgian Institute of Natural Sciences (a federal entity), and conducted by the Institute and other research institutions. He described the importance of coordinating programs through a central organization so monitoring insights can be used to adapt future monitoring requirements. He said that most monitoring data have been collected at small scales, which do not contribute to the understanding of wider ecological impacts or of whether these changes are meaningful. Monitoring at a spatial scale that encompasses multiple wind farms is important for detecting meaningful changes. He used the example of a study measuring benthic species richness in wind farms.[13] The study found a 190% increase in benthic species richness within a wind farm. However, across the Belgian North Sea, there was no increase in species richness overall because all species were already present in the area.

Degraer described the importance of identifying operational questions that can be measured to answer broader questions about whether a resource may be impacted by offshore wind. For example, “How much change is there in juvenile mortality due to piling noise?” is an operational question that contributes to the broader understanding of the question, “Do offshore wind farms impact cod fisheries?” He suggested a two-track monitoring system: (1) basic monitoring to observe the system in a specific area, and (2) targeted monitoring to measure cause-and-effect relationships that can be applied broadly. The challenge for designing targeted monitoring is identifying these operational questions and appropriate monitoring designs (such as BACI or gradient) that can provide useful information. During the discussion period, there were questions about what defines the geographic boundaries of the region that needs to be monitored and Degraer suggested that this can be answered once the operational questions about the species and ecosystem process of interest have been identified.

John King from the University of Rhode Island described methods and tools for habitat mapping and monitoring. The biotic and abiotic components of the ocean habitat vary widely in their spatial and temporal scales, ranging from the seasonal presence of local fauna up to the regional geology formed over long time scales. These scales correlate with the sampling effort and monitoring tools required; the more spatially or seasonally variable a component is, the greater the sampling frequency or spatial scale required to capture its variability (see Figure 2). He noted that usually there is a tradeoff between collecting detailed data and being able to survey a large area. King described the efforts to monitor the impacts of the Block Island Wind Farm through the ongoing Real-time Opportunity for Development Environmental Observations (RODEO) study. Regional data are available from the development of the Ocean SAMP, but there is largely an absence of baseline data. Additionally, monitoring efforts were initiated 18 months after construction, a delay he identified as a loss of important data. He described the hypothesis-driven program to monitor habitat impacts from the wind farm in a gradient design, which is designed to relate changes to

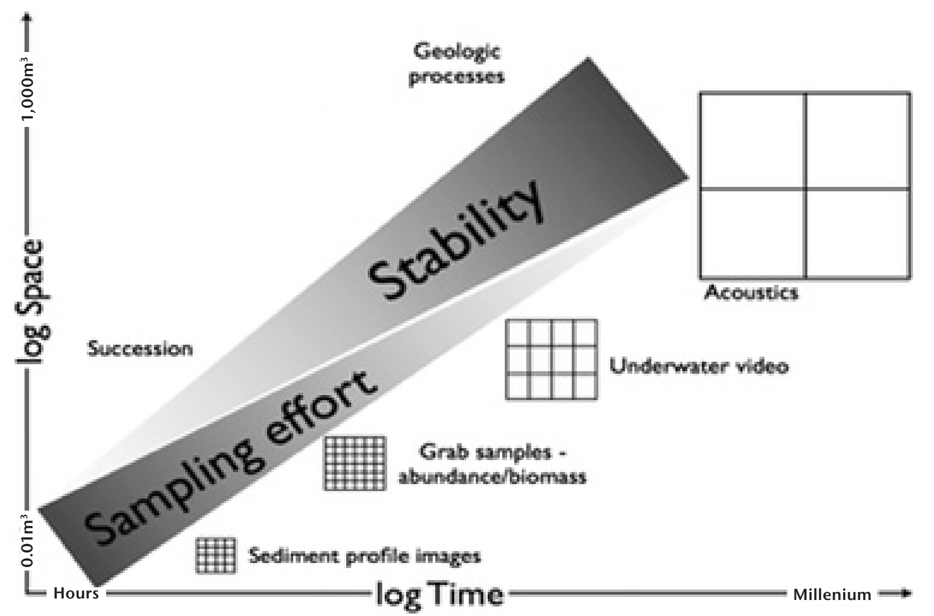

FIGURE 2. The figure shows different sampling strategies applicable at different spatial and temporal scales, dependent on habitat characteristics of interest. SOURCES: Presentation by John King; figure from Guarinello, M., E. Shumchenia, and J. King. 2010. Marine Habitat Classification for Ecosystem-Based Management: A Proposed Hierarchical Framework. *Environmental Management* 45(4):793–806.

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[13] Rumes, B., D. Coates, I. De Mesel, J. Derweduwen, F. Kerckhof, J. Reubens, and S. Vandendriessche. 2013. Does it really matter?: Changes in species richness and biomass at different spatial scales. In S. Degraer, R. Brabant, and B. Rumes (Eds.). *Environmental impacts of offshore wind farms in the Belgian part of the North Sea: Learning from the past to optimise future monitoring programmes.* Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment, Marine Ecology and Management Section. Pp. 183–189.

the benthos, including the biofouling on the turbines, to changes in fishery stocks. King emphasized that monitoring information should be targeted toward understanding ecosystem processes and that a conceptual model of an ecosystem developed in advance of the monitoring program would help target its design. In this case, the program is targeted toward understanding changes to the food web. King summarized what he considers to be the future needs and improvements to be made in habitat monitoring, including better pre-construction baseline surveys, using a food web–based approach to monitor ecosystem processes, robust statistical design, and aligning spatial scales with the monitoring goals.

Gopu Potty from the University of Rhode Island described his work modeling the propagation of sound waves from wind platforms, which takes the form of acoustic pressure and particle motion, and commented on how this information can contribute to understanding the effects of sound on fish. Pile driving during construction of wind turbines is a complex source of sound; the noise propagates and attenuates through both the water and sediment and also creates waves at the interface of the two, known as Scholte waves or ground rolls. Particle motion can be measured using geophones or calculated from measurements of pressure gradients from pressure sensors. Using observational data, Potty and collaborators developed a model of sound propagation from vertical pile driving.[14] However, the Block Island turbine piles are not vertical and their angle adds to the complexity of the propagation, requiring additional computing power for a 3-dimensional model that is currently under development.

Once the frequency of a resulting sound wave is known, Potty said it can be related to information known about fish sensitivities to sound and thresholds for meaningful impacts. Fish detect the particle motion caused by sound waves in their otolith organs and many species also detect pressure in their swim bladders, which reradiate the waves in the form of particle motion. Fish hear sounds at frequencies of 5 kilohertz and lower, which is similar to the range produced by wind turbines. Fish with swim bladders appear to respond to sound in a wider range of frequencies compared to those that detect only particle motion. However, there is a broad range of sensitivity to sound across species and the resulting behavioral responses of many species to sound are not known. Additionally, poorly monitored acoustic conditions have made it difficult to determine if fish are responding more strongly to pressure or particle motion. There are no regulatory standards for sound exposure for fish like there are for marine mammals, but Potty referenced a set of guidelines that have been developed that do contain thresholds for effects on fish, which are specified for mortality, injury, changes in hearing sensitivity, masking of other environmental noises, and changes in behavior.[15] These thresholds generally range from 180 to 220 decibels (dB). As part of the RODEO study, Potty participated in acoustic measurements during the construction of the Block Island wind turbines and twice made further measurements during operations. During construction, the particle velocity from pile driving was highest at the seabed, up to 186 dB, which are levels likely to be detected by fish. Levels are much lower during operations, at about 100 dB. He concluded that while there is an ability to model what acoustic changes will occur in the environment, more biological research is needed to interpret what the impacts of these acoustic effects may be.

David Secor from the University of Maryland Center for Environmental Science described experimental monitoring design considerations, with an emphasis on monitoring migratory fish. He noted that the BACI design may have issues when not designed at the proper scale to capture the ecosystem components that cause natural variability and suggested the use of the before-after-gradient design around a wind turbine. He described a telemetry study for black sea bass migration through the Maryland WEA, where fishermen are concerned about the effects of noise. A gradient design was developed, with monitoring locations based on the expected zones of lethal impacts, sublethal impacts, detection, and a control zone. Fifteen black sea bass were tagged with transmitters. Though a tower ultimately was not built, he was able to test the study design by measuring the behavioral response to Hurricane Hermine and the associated rapid changes in water temperature. The hurricane resulted in a partial evacuation of the fish from the area, and Secor noted that, had the experiment been measuring the impacts from the turbine, the scale of the experiment would need to be large enough to capture how temperature variability affects the population. Secor and a colleague also collected baseline data for fish migration through the Maryland WEA. They used a gradient design across the WEA, further inshore, and out at sea. More than 500 striped bass and 1,000 sturgeon were tagged with transmitters. The gradient design showed that depth is a factor in the migration pattern for each species. They found that migration patterns also vary seasonally. Secor concluded with the point that important natural gradients (e.g., depth and seasonal temperature signals) will need to be accounted for when trying to identify impacts attributed to a wind farm.

Manderson agreed with the importance of seeing the ocean as a dynamic environment and thus the need to monitor at scales that capture this variability. He pointed out that ocean observing platforms collect real-time data on wind speeds, water temperature, wave height, and other environmental parameters, so management programs should not treat the ocean as static. Creating models of the environmental parameters that affect fish productivity allow for ecosystem-scale fishery stud-

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[14] Huikwan, K., J. H. Miller, and G. Potty. 2013. Predicting underwater radiated noise levels due to the first offshore wind turbine installation in the U.S. *Proceedings of Meetings on Acoustics* 19(1).

[15] Popper, A., A. Hawkins, R. Fay, D. Mann, S. Bartol, T. Carlson, S. Coombs, W. Ellison, R. Gentry, M. B. Halvorsen, S. Løkkeborg, P. Rogers, B. Southall, D. Zeddies, and W. Tavolga. 2014. *Sound Exposure Guidelines for Sea Turtles and Fish: A Technical Report* prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. *Spring Briefs in Oceanography.*

Gillnetter in Thanet Offshore Wind Farm (Credit: Lorelei Stevens, Commercial Fisheries News)

ies when data collection at this level is not possible. Manderson described a spatial model of winter habitat for Atlantic mackerel, based on data from the fishing industry, in which mackerel presence is associated with water temperature. He said that although temperature is not the only determinant of mackerel habitat, focusing on a dominant parameter is useful for creating models at large scales. He was able to see that mackerel migrate from the North Atlantic to the Mid-Atlantic Bight to overwinter, so there is a need for connectivity between these regions. This spatial model can be overlain with expected wind farm areas and other management closures to identify how much mackerel habitat may be restricted in the future. Due to annual variations in water temperature, suitable winter habitat for mackerel varies annually and, on average, has been decreasing since the 1800s. He emphasized that in this context, wind farms are seen by the fishing industry as yet another constraint on fishing. Fishermen typically fish for multiple species so that their business has some resilience when one stock decreases. A reduction in one of their options decreases their ability to deal with this risk. Manderson suggested that it should be possible, and important, to monitor the economic impacts of changes to fisheries resources for not only the fishermen but for affiliated sectors such as gear producers, shoreside processers and distributors, and domestic and international markets.

Michelle Bachman from NEFMC continued the discussion about considering management concerns to inform the offshore wind monitoring endpoints. As a priority for the Council, she focused on the importance of knowing how wind farms may affect EFH. EFH is delineated with a map and a description of the habitat for a stock managed by regional Councils or by the Atlantic States Marine Fisheries Commission to spawn, breed, feed, and grow. The Council is not a research organization and relies on the collection of the appropriate data to inform its EFH designations. She noted that the New England WEAs overlap with the EFH of some species of concern due to their depleted status or lack of data, such as yellowtail flounder, winter flounder, Georges Bank cod, and ocean pout. Stock assessments have limitations that affect their accuracy and the impact of wind farms will create additional uncertainty, adding to the difficulties of making informed decisions about managing a species. She also stated that the cumulative effects of multiple wind farms are important to consider. She suggested that the role the Council can play in this issue is to act as a forum for conversations and consensus building about planning monitoring programs.

MODELS AS FRAMEWORKS FOR RESEARCH AND MONITORING

In the final session of the workshop, several speakers covered in-depth examples of models that can be used as frameworks for measuring and evaluating changes in the environment. Changshen Chen from the University of Massachusetts Dartmouth described the use of models to predict changes to environmental conditions from wind turbines and how changing conditions might affect biological processes. Sea scallops were used as a test case because ocean circulation patterns connect Georges Bank, east of Massachusetts, to the Mid-Atlantic Bight, allowing scallop larvae to disperse and settle westward. The WEAs in southern New England are located within this path of dispersal and Chen and colleagues developed a model to answer the question of whether wind turbines may affect the transit of larvae that supply the fishery in the Mid-Atlantic Bight. Chen and collaborators used the Finite-Volume Community Ocean Model (FVCOM), nested within the Northeast Coastal Ocean Forecast System (NECOFS), to model the physical ocean and atmospheric dynamics in southern New England. The model considered hypothetical placements of wind turbines, but can be rerun when exact locations are identified. When the model is run using historic conditions, it shows that wind turbines will change circulation and wave heights with a resulting change in the dispersal and settlement of the larvae.[16] However, Chen noted that this does not determine if this is a meaningful impact to the fishery, but is a starting point for future analysis.

Sarah Gaichas from NOAA's NEFSC described NOAA's integrated ecosystem assessment (IEA) framework for implementing ecosystem-based management. Ecosystem-based management is useful for managing multiple activities, which is needed for managing fisheries and offshore wind. IEA starts with an identification of the management objectives, which drives the selection of indicators, ecosystem assessments, risk analysis, and the creation of management strategy evaluations (MSEs). Gaichas used an example of efforts in the mid-Atlantic to help guide management decisions made by the Mid-Atlantic Fishery Management Council. She shared a conceptual model of the regional environment, which includes parameters for habitat, food web dynamics, and managed species in the mid-Atlantic, which are linked in the model to the human activities, social factors, and management objectives. Within this model, it is the human activities that are the targets of management actions and objectives. The risk assessment component of the IEA is a qualitative process for identifying which indicators are at the highest risks for meeting management objectives and most in need of an MSE. As an example, she shared a conceptual model for the management of scup, summer flounder, and black sea bass. The conceptual model describes the relationships between activities and resources in the area, either qualitatively or through physical models, developed based on expertise in how these parameters interact. The conceptual model currently does not include the offshore wind, but it could be incorporated. During the discussion, Gaichas expanded on how this framework could support monitoring programs. Before much data have been collected, a qualitative network analysis based on a conceptual model uses generalized positive and negative relationships based on expert opinion to provide an initial understanding of where management tradeoffs or issues may arise in a system. Later, data collected from monitoring programs can also be used to identify the effects of management decisions on the ecosystem indicators of interest.

Eileen Hofmann from Old Dominion University described an MSE developed in coordination with members of the surfclam industry to evaluate and quantify the environmental variables affecting surfclam distribution. The geographic range of the fishery has been moving further northward and offshore since the 1970s. The MSE considers factors that may affect surfclam range, such as fishing and changes in climate, using a set of models that define the linkages among physical, biological, ecological, economic, and management components of the system. The physical and biological models in the MSE show that the southward dispersal of larvae is limiting the expansion of the species northward toward more favorable conditions. The economic component of the MSE incorporates the activities of the fishing industry to model how surfclam landings are related to fishing effort, vessel size, and other metrics. With the biological and economic information combined, options for managing the fishing industry can be evaluated by how they will impact the fishing industry and fishing resource. During the discussion, it was noted that the surfclam MSE benefited from robust datasets that are not available for many other stocks, but Hofmann emphasized that MSEs still provide frameworks for discussions about priorities and uncertainties even for fisheries lacking this degree of information.

CONCLUDING REMARKS

At the conclusion of the workshop, all attendees were asked to share what they identified as take-away messages. In response to a question about how engagement among BOEM, fishermen, and fishery scientists can continue, Smolowitz said that there are models within fishery management that could be applied to engagement with offshore wind. He noted particular success of engagement in scallop management through the use of stakeholder panels, scientific panels, and management panels within the regional fishery management councils. Wallace reiterated what several panelists had noted: that there is a feeling that fishermen have not been sufficiently engaged. The importance of regionally focused advisory groups that can provide coordinated input was supported by several audience members. However, attendees noted that who exactly will be responsible for implementing and coordinating regional monitoring programs or managing advisory panels still appears to need to be determined.

Some attendees also raised the importance of using monitoring programs to ultimately inform decision making. Cohen noted that the question of what the impacts to fisheries will be is partly a biological one, but also a management question dependent on how wind farms may be sited and what fishery access rules will be. He noted that in the United Kingdom monitoring cannot influence the siting of wind farms because they are already in place, but it can inform decisions about mitigating the impacts of the wind farm. Stokesbury noted that the standards for monitoring information will be important to identify and will depend on the ultimate use of the monitoring data.

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[16] Chen, C., R. Beardsley, J. Qi, and H. Lin. 2016. *Use of Finite-Volume Modeling and the Northeast Coastal Ocean Forecast System in Offshore Wind Energy Resource Planning.* Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. BOEM 2016-050. 131 pp. https://www.boem.gov/NE-Ocean-Forecast-Model-Final-Report.

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